SEASONAL AND DAILY VARIATION IN DISTRIBUTION AND ABUNDANCE OF SOME SHALLOW WATER BENTHIC MARINE FISH SPECIES OF LOGY BAY, NEWFOUNDLAND, WITH SPECIAL REFERENCE TO **MYOXOCEPHALUS SCORPIUS** AND **M.** OCTODECEMSPINOSUS

V. A. PEPPER

SEASONAL AND DAILY VARIATION IN DISTRIBUTION AND ABUNDANCE OF SOME SHALLOW WATER BENTHIC MARINE FISH SPECIES OF LOGY BAY, NEWFOUNDLAND, WITH SPECIAL REFERENCE TO *MYOXOCEPHALUS SCORPIUS* AND *M. OCTODECEMSPINOSUS*

by

© V.A. Pepper, B.Sc.

A Thesis submitted in partial fulfilment
of the requirements for the degree of
Master of Science

Department of Biology
Memorial University of Newfoundland
St. John's Newfoundland

March 1974

ABSTRACT

Investigation of the seasonal and daily movements of some shallow water benthic marine species in a small, rock bounded "gulch" of variable depth in Logy Bay, Newfoundland, revealed that two species of sculpin, Myoxocephalus scorpius and M. octodecemspinosus were the most common fish inhabitants of the area. M. octodecemspinosus dominated the area's fish fauna during the summer months. Although M. scorpius was a year round inhabitant of the area, its population was greatly decreased in the winter. Analyses of distribution patterns for these two species indicated that M. octodecemspinosus ranged through the depth gradient of the gulch and occupied various types of open bottom terrain. M. scorpius was more common in the lower reaches of the gulch and was associated with cover throughout the summer months. This cryptic behaviour subsided during the winter months subsequent to the fall emigration of M. octodecemspinosus from the area.

Stepwise multiple regression and correlation analyses of the numbers of M. scorpius, M. octodecemspinosus and Stichaeus punctatus per unit area suggested that, of the physical and biological parameters examined, photoperiod, temperature and the degree of water movement were correlated with the abundance of these benthic fish species in the study area. Linear prediction models of abundance of M. scorpius, M. octodecemspinosus and S. punctatus per unit area are presented. Deficiencies of these models are discussed.

Observations of M. scorpius and M. octodecemspinosus at night suggest interspecific avoidance by reciprocal movements into and out of the study area at dawn and dusk. The numbers of M. scorpius present in the study area decreased at dusk and increased again at dawn.

Pseudopleuronectes americanus was abundant in the area from late May to September. A dense aggregation of P. americanus observed after dark in late June is described.

Times of immigration and emigration of Limanda ferruginea were similar to those of P. americanus.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENTS

The author wishes to express his gratitude to the many people who have assisted in this research. Thanks are due to the Marine Sciences Research Laboratory diving facility for use of equipment and personnel. Diving assistance was also provided by: Chris Campbell, Joe Brown, Bruce Jenkins, Bruce Bennett and Lou van Guelphen, all presently students of Memorial University and G.R. Holdren of Johns Hopkins University, Baltimore, Md. I wish to thank these individuals for so much of their time and enthusiasm.

The personnal of Newfoundland and Labrador Computer Services provided invaluable assistance in execution of the multiple regression program. I would also like to thank Dr. D.R. Idler, Director, M.S.R.L., for use of his computer account and general marine lab support throughout this research. My thanks also go to Dr. R. Strickler of Johns Hopkins University, Dr. D. Copeman of Memorial University and Mr. S. Eyres for many lengthy discussions of statistics.

Dr. C.W. Andrews and Dr. D.H. Steele read and criticized the manuscript. Their contributions are gratefully acknowledged.

I would especially like to thank Dr. J.M. Green for his supervision of this project. His financial support during the summer of 1973, his many helpful suggestions, encouragement and, especially, his friendship are appreciated.

Memorial University of Newfoundland facilitated this research with both equipment and a fellowship.

INTRODUCTION

Of the many marine habitats, those of shallow water communities are among the most accessable. Although species diversity is characteristically low in subarctic habitats (Paine, 1966; Sanders, 1968), abundance of individual species near shore varies greatly both seasonally and daily. Low species diversity in the cold waters of eastern Newfoundland is of value to marine ecological studies in permitting concentration on a few species without the complicating interactions found among more diverse communities. The present study describes seasonal and day to day variations in distribution and abundance of some inshore benthic fish and evaluates factors that may be associated with these variations.

Associated with the appraisal of seasonal and daily changes in distribution is the question of how large an area individual fish cover in their movements. Among the inshore marine fish species, are individuals restricted in their movements to a small geographical area or are they transient in such areas?

Questions of population regulation are greatly facilitated by short food webs. Such food webs are common in arctic and subarctic marine environments (Paine, 1966). One objective of this research was to determine the extent to which shallow water benthic fish species prey on one another. Another objective was to investigate other possible means of population control among benthic fish species.

This study uses SCUBA to observe benthic fish in their natural habitat and concentrates on species which show no apparent aversion to SCUBA.

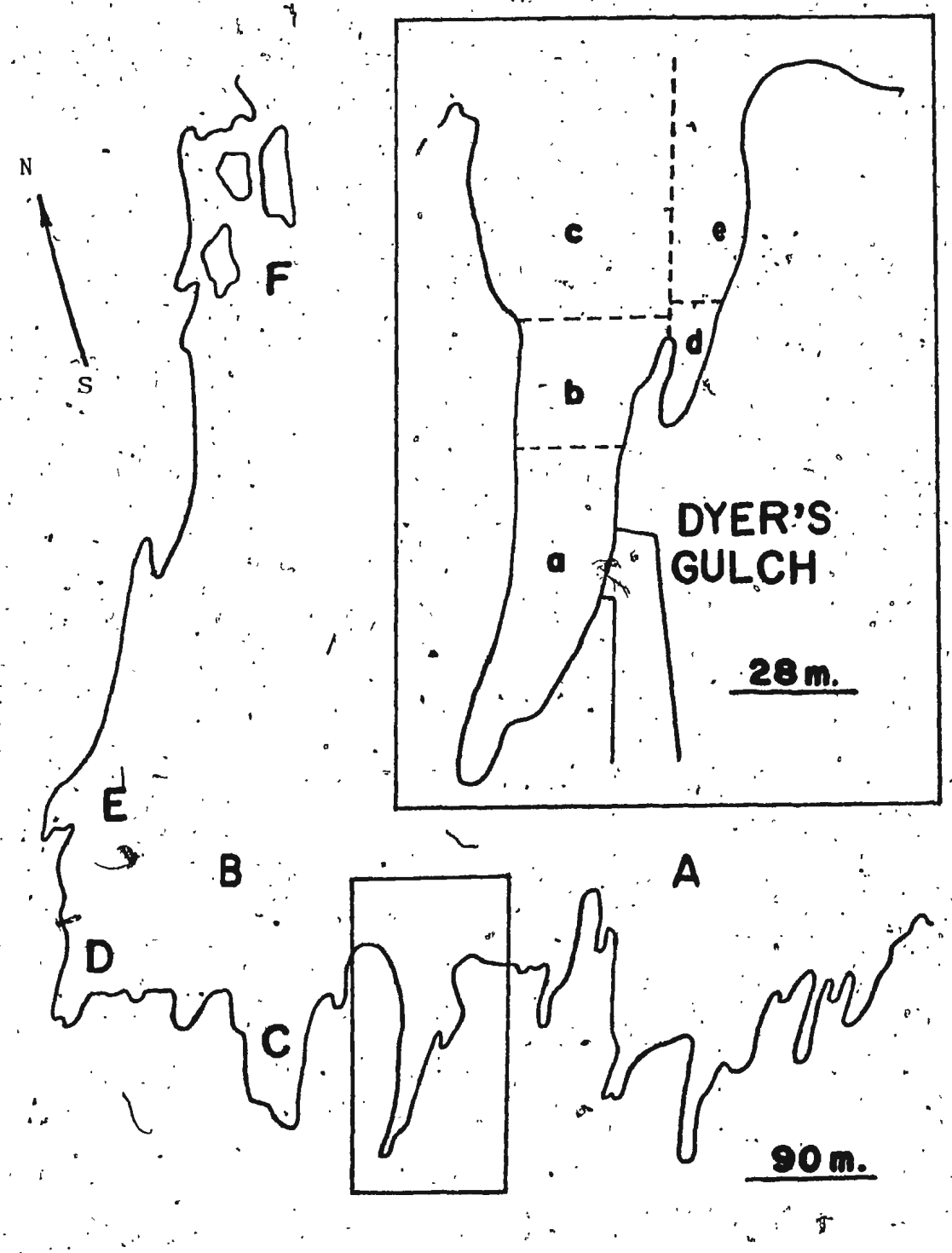


Figure I. Dyer's Gulch and peripheral study areas

Study Area

Immediately adjacent to the Marine Sciences Research Laboratory, by which access is gained to Logy Bay, is Dyer's Gulch. This gulch was used as the main study area.

The depth profile of this gulch ranged from approximately two metres at its shoreward origin to a depth of 22 metres approximately 170 metres seaward. At a distance of 80 metres seaward from its origin, the depth suddenly increases from six to nine metres. The substrate in Dyer's Gulch varies from boulders interspersed with gravel within the first 70 metres, to a cobble plateau beginning about 100 metres seaward. This plateau is not homogeneous for the entire width of the gulch at this point (40 metres wide). A narrow belt of boulders runs seaward along the southeast gulch perimeter. This area contrasts sharply in appearance with the comparative regularity and smoothness of the cobbles of the plateau. The depth of this boulder belt is 0.6 metres greater than the plateau for its initial 25 metres. A detailed description of the submarine characteristics of Dyer's Gulch is given by Himmelman (1969). The study area was subdivided into sampling sites according to differences in depth and type of substrate (Fig. I).

To facilitate research on movements of benthic species from Dyer's Gulch to peripheral areas, additional observations were made in Logy Bay at varying distances from Dyer's Gulch (Fig. I). These areas were chosen according to their accessability and proximity to Dyer's Gulch.

Benthic Fish Species

Himmelman (1969) cites several fish species as being common in Dyer's Gulch. For convenience, these species are divided into two size groups. Larger species (ie. total length greater than 20 cm.) include the adults of lumpfish, Cyclopterus lumpus; winter flounder, Pseudopleuronectes americanus; longhorn sculpin, Myoxocephalus octodecemspinosus; shorthorn sculpin, M. scorpius; and yellowtail flounder, Limanda ferruginea. Smaller species include arctic shanny, Stichaeus punctatus; radiated shanny, Ulvaria subbifurcata and sea snail, Liparis atlanticus.

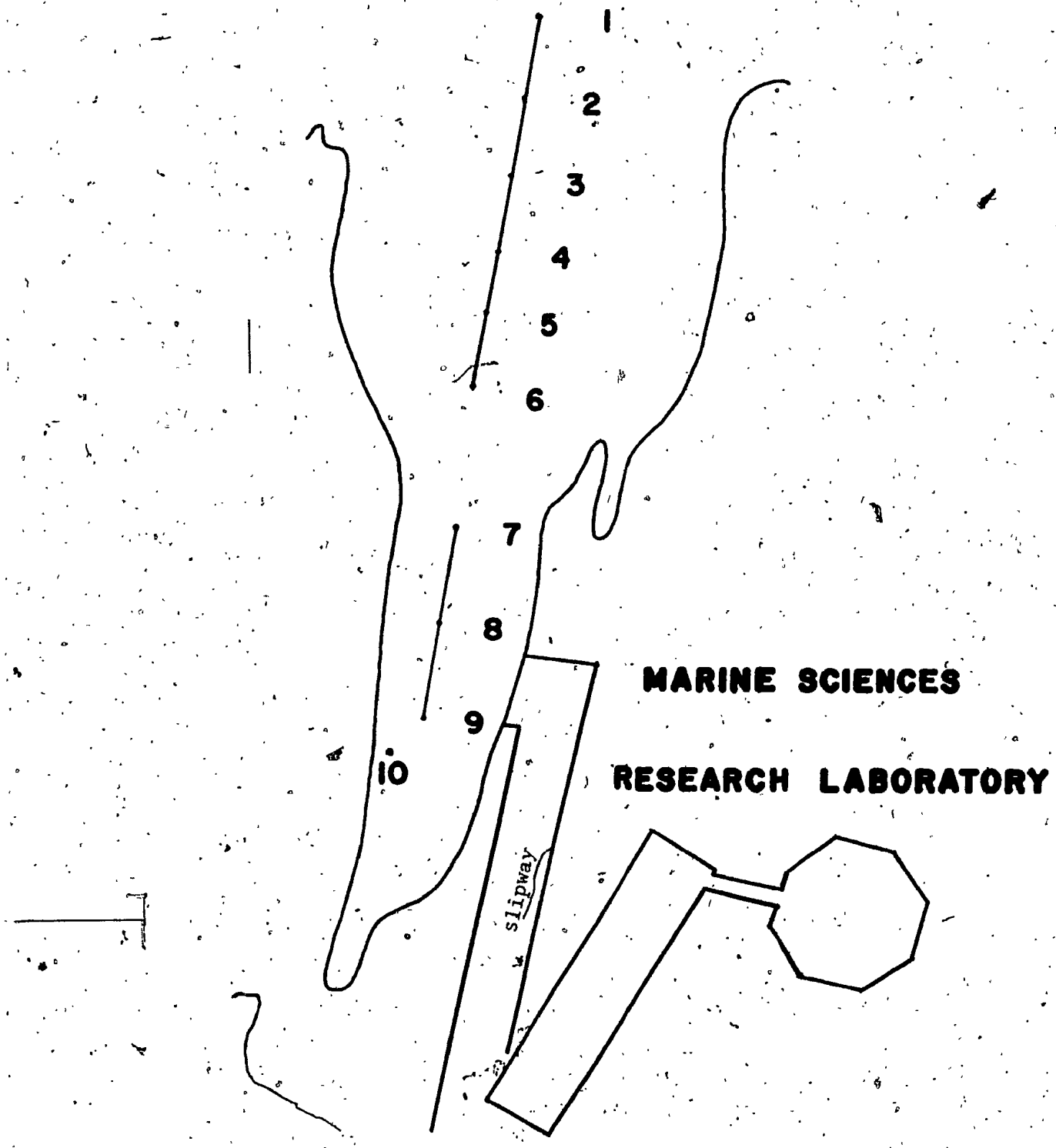


Figure II. Relative positions of sampling stations in Dyer's Gulch

METHODS

Species Enumeration

Dyer's Gulch is well defined by rock outcrop inclosing an area of about 6,500 square metres. The larger, easily observed benthic species, could be surveyed by swimming a constant search pattern through the study area at a distance of one to two metres above the substrate. The search pattern was accomplished by two divers swimming side by side out one side of the gulch and back in on the other side, thus describing a "U".

Investigation of the smaller species necessitated detailed inspection of the substrate and therefore the use of a smaller unit of sampling area. Accordingly, a portable, dexion, square quadrat, measuring one metre per side was used to delimit the substrate area to be inspected. The positions at which the quadrat was placed were determined by measured transects. Two transects of braided, 6.3 mm. diameter polypropylene rope were marked at ten metre intervals in the laboratory. The longer of the two transects (50 m.) was established horizontally on the bottom in site c and the smaller (20 m.) in similar manner in site a (Fig. II). This resulted in six sampling stations in the former site and three in the latter. An additional station was chosen in site a. This station (#10) was selected on the basis of its being well defined by surrounding boulder and cliff. The individual sampling stations were not random but rather fixed from one observation period to another. This procedure was designed to facilitate documentation

of territoriality and/or restricted movements of individuals.

The two transects were anchored by tying the ends to boulders and weighting the intervening length with rocks. For each transect, the exact position of the seaward end was chosen according to the availability of suitable anchoring boulders.

Whenever possible, counts were taken once per week from early August to late November, 1972 and February to December, 1973.

Tagging

The larger species were tagged to enable individual recognition. Dart type tags manufactured by Floy Tag and Manufacturing Inc. of Seattle (Type FD-67. Anchor tag #20, 5/8 inch bare monofilament) were used. All tags were permanently marked with a five digit number in consecutive series by the vending company.

Fish for tagging, from Dyer's Gulch, were captured with a hand net and removed from the water long enough to allow them to be measured and tagged in the dorsal musculature of the left side (right side for flounder). After tagging, the specimens were released at the slipway (Fig. II). In making an observation, the relative position of the fish and its tag number were recorded on an underwater slate. Tagged fish were not recaptured during the study period. This avoided accidental removal of the tag and interference with the normal activity of the fish.

Tagging operations did not follow a rigid schedule. Instead, tagging was undertaken subsequent to any dive in which more than ten individuals of a particular species were recorded. A total of 265

longhorn and 132 shorthorn were tagged.

Sonic transmitters (Smith-Root, SR-69) were used on six longhorn and three shorthorn sculpin to provide more extensive information on movements of individual fish. These sonic tags were usually implanted in the stomachs. One experiment was undertaken in which the sonic tag was inserted, surgically, into the body cavity. For this experiment, antiseptic surgical techniques were used in the laboratory on two anaesthetized longhorn sculpin. A small, mid-ventral incision was made in the vicinity of the pelvic fins. The sonic tag was inserted in one specimen while a plugged and weighted, plastic centrifuge tube was placed in the other specimen. Both incisions were sutured. The specimens were given an intramuscular injection of penicillin (Derapen-C. 0.1 cc.) and placed in holding tanks to recover. Both specimens were also tagged externally to enable individual recognition. The sonic tagged fish was released at the slipway approximately 20 hours after the operation.

A third method of tag placement involved attaching a single barbed fish hook to a sonic tag and sewing the hooked tag into the abdominal cavity of a caplin. The caplin was then taken to the study area and offered as food to a previously marked fish. This final technique had the advantage of not requiring any physical human contact with the experimental specimen.

Two types of hydrophone were used to determine the position of the sonic tagged fish. One hydrophone (Smith-Root, UL-74) could be

carried by a diver. This receiver was used to retrieve sonic tags underwater. The second hydrophone was used from a surface vessel to obtain the relative position of the sonic tagged subject. This second hydrophone was designed by Stasko and Polar (1972) and was built by the Department of Technical Services of Memorial University of Newfoundland.

A total of 49 longhorn and 28 shorthorn from areas peripheral to Dyer's Gulch were marked during the summer of 1973. Fish from areas A and B were tagged on two separate dates for each area. Fish from area D were tagged on only one occasion. Fish from area A were tagged and released at the surface in area A on the first tagging trial outside Dyer's Gulch. Subsequent to this, fish tagged in areas other than Dyer's Gulch were tagged underwater. At such times, no measurements were taken.

One to three sculpin specimens were selected, irregularly, from among the Dyer's Gulch fish fauna for analysis of stomach contents. The emphasis on behaviour in this study prohibited the removal of large numbers of fish. Accordingly, the em tic described by Markus (1932) was used to obtain stomach contents. To determine the effectiveness of this solution, the stomachs of a few specimens were examined after sufficient time had passed for the chemical to act. Specimens which were to be returned to the gulch subsequent to use of the emetic were kept in the laboratory over night and released the next morning.

Stomach contents were preserved in 10% formalin. They were

examined to determine the relative abundance of particular food items in the stomachs.

Abiotic Parameters

The parameters examined as possibly influencing the movements of the fish species of Dyer's Gulch were: water movements, temperature, radiant energy influx, photoperiod, precipitation, salinity and the ambient concentrations of the heavy metals, magnesium, manganese, iron, copper, zinc and lead.

Water Movements

No attempt was made to directly quantify submarine water movements. Water movement was coded by visual inspection of surface conditions in Dyer's Gulch. The code used here is the same as that used in the M.S.R.L. diving log.

0 No swell, surface glassy
1 No swell, surface with wavelets
2 No swell, surface choppy
3 Slight swell (1-3 ft.), surface glassy
4 Slight swell (1-3 ft.), surface with wavelets
5 Slight swell (1-3 ft.), surface choppy
6 Moderate swell (4-6 ft.), surface glassy
7 Moderate swell (4-6 ft.), surface with wavelets
8 Moderate swell (4-6 ft.), surface choppy

The degree to which submerged objects are affected by surface waves has been well defined as a function of both wave height and depth (Carstens, 1968). This code then will represent changing

conditions of water movement at the benthic community in Dyer's Gulch but is not sensitive enough for intersite comparisons.

Temperature

Temperature was measured at the bottom using a laboratory thermometer. Temperature was recorded for stations 1 and 10 and was taken in close proximity (2 cm.) to the substrate.

Radiant Energy Influx

Continuous data on light intensities were obtained from the monthly radiation summary published by the Meteorological Service according to the "Manual of Standard Procedures and Practices for Measuring Electromagnetic Radiation of Atmospheric, Solar and Terrestrial Emission." These data were recorded at the Research Station of the Canada Department of Agriculture in west St. John's. The unit of measurement is the $gcal/cm^2$.

Conversion of these data into values representative of radiant energy received at the benthic community was achieved by use of the equation:

$$Id = Io_e^{-kd}$$

where

Id = radiant energy received at a particular depth

Io = radiant energy received at the surface

e = base Napieran logarithm

k = the extinction coefficient

d = depth in metres

The mean depth of each of the sampling stations was used in association with an extinction coefficient of 0.15 (Clarke and Denton, 1962).

Photoperiod

These data were taken again from the Monthly Radiation Summary. Hours during which radiation was recorded were totaled to give daily figures.

Precipitation

Measurements of precipitation for the St. John's area were taken by the Atmospheric Environment Service at the St. John's airport.

Water Sampling

To facilitate laboratory determinations of salinity and metal concentrations, water samples were collected once per week whenever possible. Plastic, screw cap bottles were filled with surface water at the slipway, immediately prior to entering the water. This was a precautionary measure to prevent the bottles being crushed at the depth of station one (11.6 m.). When taking a sample, the bottle was evacuated using the SCUBA regulator exhaust vent, held upside down until in close proximity to the substrate of the particular station, then inverted, thus allowing it to fill. Once the bottle was full of water, the cap was replaced immediately. Each sample was approximately one litre.

Salinity

This parameter was determined in the laboratory with an American Optical T/C refractometer (Model 10423). Salinity determinations on water samples were alternated with readings on distilled water to assure calibration of the instrument. Readings were taken to the nearest part per thousand.

Metals

All metal concentrations were determined according to the procedures of Traversy (1971) by the water analysis facility of Memorial University. Water chemistry data have been excluded from the following discussions but are included in an appendix.

Data Analysis

Preliminary statistical analyses (χ^2, t, analysis of variance) were performed on a Wang, 700 series, Advanced Programming Calculator. Stepwise multiple linear regression was performed by an IBM, system 370, model 155 electronic computer using the IBM, Scientific subroutines, stepwise multiple regression program.

RESULTS

Preliminary observations in the main study area revealed two benthic species not documented by Himmelman (1969). The ocean or eel-pout, Macrozoarces americanus and the sea raven, Hemitripterus americanus were observed in Dyer's Gulch on several occasions in the spring and summer. Two wolffish, Anarhichas sp. were noted in Area D on July 6, 1973.

Of the larger species, the two species of sculpin were the only fish on which extensive information was recorded. Qualitative information on seasonal occurrance was recorded for all species.

Among the benthic fish species which have been designated as smaller species, adults of U. subbifurcata were found to be nocturnal and were not seen during day time observation periods. They have been omitted from this study. The presence of numerous young of the year ocean pout and juvenile sculpin resulted in their inclusion in the group designated as smaller species. Numbers of larger species given in this report, unless otherwise specified, represent only tagged specimens seen. Total numbers seen during any one observation period are given in Appendices I and II.

Seasonal Occurrance

M. scorpius

The shorthorn sculpin is found in Dyer's Gulch throughout the year although only five specimens were counted during the winter. Throughout January and February, observations of M. scorpius were

usually of egg guardians. However, as these fish were not tagged due to feared interference with normal incubation behaviour, the identity of individuals could not be ascertained unless the individual was guarding one of the known egg masses. All four egg masses observed were eventually deserted by the adults and were destroyed by amphipods and holothiurians.

Relative to the number of longhorns present in Dyer's Gulch during the summer, the shorthorn was never very abundant. Even during their peak of abundance in June, there were never more than ten shorthorns counted in the study area during any one observation period.

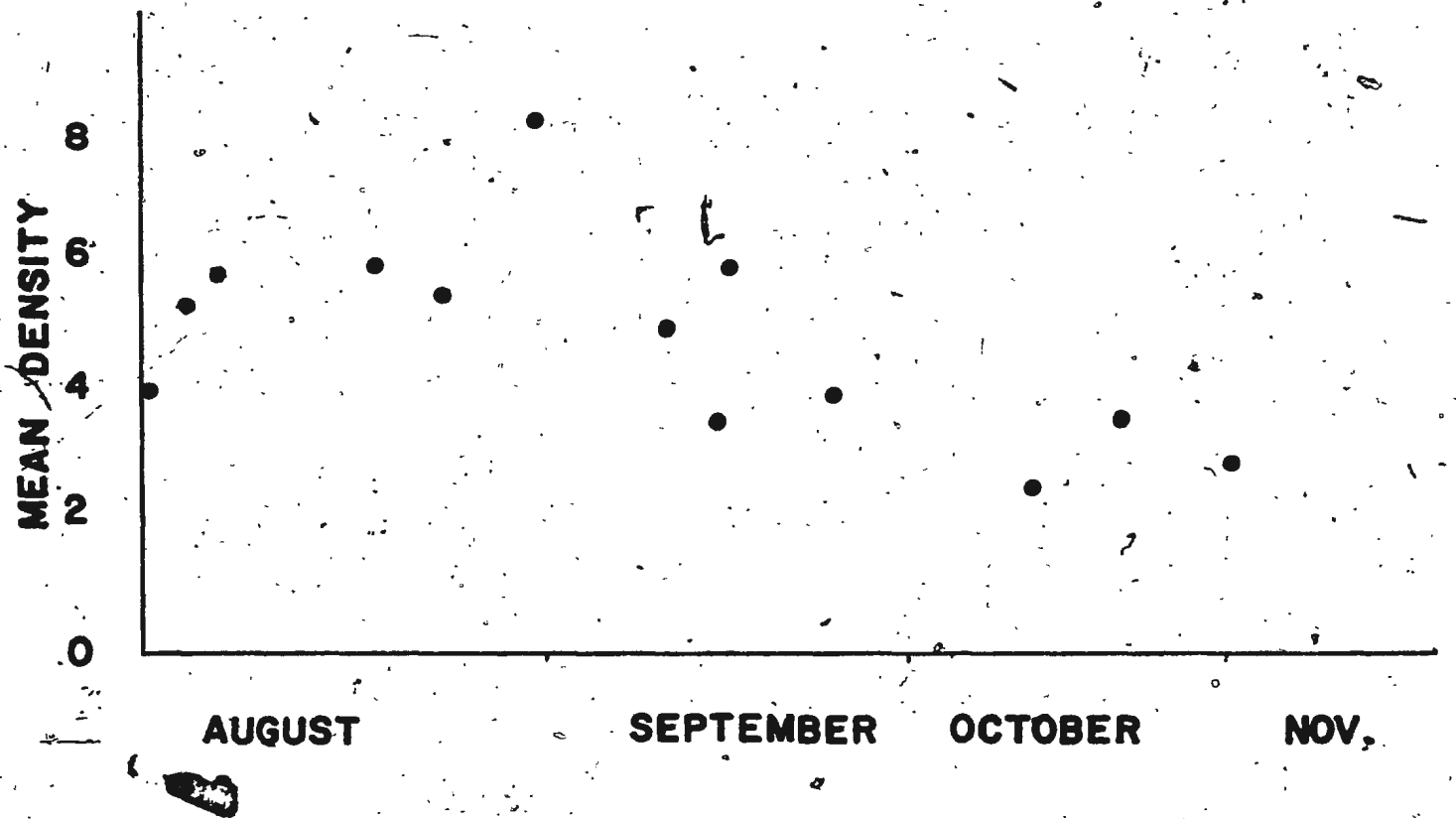
M. octodecemspinosus

The longhorn sculpin is a seasonal immigrant to Dyer's Gulch. It is the most abundant benthic fish throughout most of the summer. In 1972, all the longhorn sculpin had emigrated from the main study area by November 28. migration, in 1973, took place by October 24. In each year there was heavy surf action between the last observation of longhorn sculpin in the area and the first observation in which longhorns were absent. Although a single longhorn was observed as early as March 20, 1973, this species was not regularly encountered until mid May. Longhorn sculpin began to dominate the Dyer's Gulch fish community in number in early June.

P. americanus

The first observation of winter flounder in Dyer's Gulch in 1973

Figure III. Mean number of S. punctatus per square metre in 1972.



was on May 15. Most winter flounder observations were in the lower reaches of the gulch (sites c, d, e) although, occasionally, individuals were found in site a. Several gravid females were seen in site c in late May. Winter flounder were found in the area until late September. No specimens were seen subsequent to October 14, 1973. The last observation of winter flounder in 1972 was on October 23.

L. ferruginea

Yellowtail flounder were also found regularly in Dyer's Gulch during the summer months of both years of this study. Their immigration into the study area was preceeded by that of winter flounder although emigration of both species coincided.

C. lumpus

Observations of lumpfish were rare. One specimen was tagged in the fall of 1972. It was never seen again. Two additional specimens were seen in 1973, one in June and one in July. No lumpfish egg masses were observed in Dyer's Gulch during the period of this study, although young lumpfish (@ 8 mm.) were found clinging to the rock cliff of site b on July 13, 1973. These young fish were attached approximately two metres up from the base of the cliff.

L. atlanticus

Extremely heavy seas in Logy Bay during early November, 1972, extensively rearranged the substrate throughout Dyer's Gulch.

Subsequent to this, except for isolated individuals in January, 1973, none of the smaller benthic species were seen in the area. Portable quadrat counts were then discontinued until L. atlanticus was noted in the area in February, 1973. The Liparis population reached a peak in April, 1973, then declined. The last sighting of a sea snail in Dyer's Gulch in 1973 was on November 7. Many of the specimens observed prior to July 18, 1973 were distinctly gravid.

U. subbifurcata

Young of U. subbifurcata were seen in Dyer's Gulch in low numbers in all but the coldest months of the year. Unlike adult radiated shanny, juveniles appear to be most active during the day.

Myoxocephalus sp.

Juvenile sculpin were not common in Dyer's Gulch prior to 1973 (Green, pers. comm.). The first sighting of individuals of this genus in 1973 was in May. They were still present in Dyer's Gulch at the end of the present study in December, 1973.

Macrozoarces americanus

Juvenile ocean pout were found in the study area for a relatively short period. They were first noted on May 15. They were not observed subsequent to August 29.

S. punctatus

The first year of this study marked the first known observation of adult arctic shanny in Dyer's Gulch. In 1972, the adults were found only beyond station #1 in a minimum depth of 20 metres. From

the time of first observation until their disappearance (Sept. 21 to Nov. 1), their presence in the study area was not noted.

Colonization of all of Dyer's Gulch by adult S. punctatus took place in 1973. Densities, however, were noticeably greater in the lower reaches of site c than in site a (maximum mean of 0.80 vs. 0.25 adults per square metre). The last sighting of an adult S. punctatus took place on December 12, 1973.

Pelagic larvae of the arctic shanny have been observed near shore in Logy Bay in late June and early July (Green, pers. comm.). They settle to the bottom at metamorphosis and become pigmented, after which they closely resemble the adults.

After residence in the area for the summer months, the population has consistently declined through the fall and reached zero as early as November to as late as early January (Farwell, 1971).

During the summer of 1972, random quadrat counts throughout the study area indicated a mean number of juvenile S. punctatus per square metre as high as 8.33. This density is markedly higher than that of the fixed quadrat series used throughout 1973. In 1973, the greatest density of this shanny was found, in late September, to be 1.37 per square metre.

Their final disappearance in 1972 was abrupt (Fig. III). They were not found in the area after high onshore winds in early November. Although onshore winds occurred during the fall of 1973, water movement comparable to that experienced the previous year did not occur.

Habitat

M. scorpius

Shorthorn sculpin are most commonly found in close proximity to rock cover although this relationship varies with season. During the summer months, shorthorns are often concealed in crevices or among boulders. This affinity for cover is reduced during the winter months, especially during the spawning and incubation periods. In only four out of fifteen observation periods (ten to twelve minutes each) were shorthorns noted on the open sandy bottom of area B. Each of these four observations were of solitary shorthorns.

M. octodecemspinosus

A noticable characteristic of the longhorn sculpin is that it is commonly associated with open bottom terrain of cobble (greatest dimension up to 0.5 m.) to sand. When present in areas of boulder substrate (greater than 0.5 m.) they are most commonly found on top of rather than hidden beside these boulders. Longhorn sculpin were present on the sandy bottom of Area B in ten out of fifteen observations. In seven of these periods, longhorn numbers were greater than five individuals.

Smaller Species

The quadrat series data of the smaller species were analysed in a two-way analysis of variance of species versus quadrat station to determine whether the individual stations adequately represented the two sites (homogeneity within sites). In one out of thirty-two

analyses, there was a significant difference among stations with respect to the numbers of fish counted (F=2.46. P=0.04). This represents 3.13 departures from homogeneity per 100 analyses and is therefore considered not significant. Homogeneity among stations with respect to the numbers of individual species indicated that these smaller species had habitat requirements similar to each other or that they were all equally diverse in their choice of habitat within the two sites.

Distribution Within Dyer's Gulch

M. scorpius

Shorthorn sculpin in Dyer's Gulch are unevenly distributed among the study sites (Table I). Observations of shorthorns in sites d and e are so few that they have been omitted from the following results. Total fish counted each day are given in in Appendix II. Data from site b have been excluded from all statistical calculations due to the absence of environmental data for this site (see Abiotic Parameters of Methods). Missing data for April and September result from failure to record positions for the shorthorns observed during observation periods in these months.

A t-test of the mean number of shorthorn in sites a and c indicates a significant difference in the numbers of fish in these two sites (t=5.19. P=0.001). Exploration of this difference requires an investigation into the biotic and physical differences

between the two sites (see Quantitative Analysis of Site Association, page 34).

Table I

Number of M. scorpius per study site in 1973

Month	Site			Total Number of Individuals Seen
	a	b	c	
January	0	5	3	5
February	0	0	3	2
March	0	3	3	3
April				2
May	2	1	4	26
June	6	3	11	29
July	11	7	10	18
August	0	3	5	2
September				3
October	0	2	6	13
November	0	1	7	7
December	1	0	7	3

M. octodecemspinosus

Longhorn sculpin are found in Dyer's Gulch only during the summer months. Table II depicts site occurrances for longhorns.

As with the shorthorn observations, data for site b have been omitted from all calculations. χ^2 contingency analysis indicates a significant difference (χ^2=22.65. P=0.001) between the periodicity of fluctuations in numbers of longhorns in sites a and c although the numbers of longhorns in the two sites at any one time may not be significantly different (t=1.98. P=0.15).

Arrangement of data as in Table III facilitates comparison of site preferences for the two sculpin species. χ^2 analysis of the

total of each species found in the respective sites indicates no difference in their relative distributions (χ^2=1.30. P=0.26).

Table II

Number of M. octodecemspinosus per study site in 1973

Month	Site			Total Number of Individuals Seen
	a	b	c	
January	0	0	0	0
February	0	0	0	0
March	0	0	0	0
April	0	0	0	0
May	0	1	1	12
June	2	12	14	80
July	40	51	35	99
August	29	23	41	42
September	0	20	15	17
October	0	2	3	7
November	0	0	0	0
December	0	0	0	0

Table III

Comparison of longhorn and shorthorn positions

Month	Longhorn			Shorthorn		
	Number *Seen	Number in site a	Number in site c	Number *Seen	Number in site a	Number in site c
May	2	0	1	7	2	4
June	28	2	14	20	6	11
July	126	40	35	28	11	10
August	93	29	41	8	0	5
October	4	0	2	8	0	6
Total	253	71	93	71	19	36

* The Number Seen includes only those fish for which positions were recorded.

Smaller Species

Between any two consecutive weeks of this study there was little change in the smaller species community, either in number

or in species (maximum F=2.03. P=0.227). In an attempt to compare sites a and c, weekly quadrat surveys were grouped into units of two weeks, thus producing eight observations per cell (four quadrats per site per week). A three-way analysis of variance (of the numbers of fish counted of a particular species in a given site over the discrete time intervals) indicated that there was a difference between the two sites (F=11.92. P=0.0006) with respect to the numbers of fish in each site. The interaction of species with time (F=4.056. P < 0.0001) indicates that the numbers of individual species varied with time when observed in both sites. The interaction of species with site (F=5.778. P=0.0001) indicates that the difference between sites varied with species when observed over time. The first outcome is to be expected as the peak of abundance does not occur at the same time for all species. (Appendix I). However, the implied difference between numbers of individuals per species in the two sites should be examined more closely in consideration of the significance of the second order interaction in the analysis (F=1.652. P=0.0016). The possibility that one species may prefer site a while another prefers site c (as suggested by the interaction of species with site) was evaluated by examining data for individual species, one at a time, in five, two way analyses.

S. punctatus

Although there was no well defined difference in the numbers of arctic shanny per square metre in the two sites in 1973 (F=1.166.

P=0.282), the first order interaction (F=2.593. P=0.0086) suggests that departures from homogeneity between the two sites may have been obscured. This significant interaction implies that differences between sites vary with time. In 1972, the S. punctatus population in Dyer's Gulch was much larger than in 1973. At that time, site a contained the greatest numbers of arctic shanny per square metre.

L. atlanticus

The difference between the mean number of sea snails per square metre in the two sites is highly significant (F=10.465. P<0.0001). The preference for site c over site a is obvious (Appendix I).

M. americanus

Again there is a definite difference between the numbers of young ocean pout per square metre in the two sites (F=5.769. P=0.0185). The population of young ocean pout in site a was less than one half that of site c.

U. subbifurcata

The analysis of quadrat counts of radiated shanny in the two sites indicated uniform distribution. This apparent homogeneity (F=1.119. P=0.293) may have been due to low population levels. The interaction of numbers of radiated shanny per square metre with time was not significant (F=1.792. P=0.124), suggesting that population size for this species did not change very much during

the period of this study.

Juvenile Myoxocephalus sp.

The number of young sculpin found in the lower reaches of Dyer's Gulch is distinctly greater than in site a (Total numbers: site a--12, site c--46). The analysis of variance supports this intuitive appraisal ($F=15.07$. $P=0.0002$).

Daily Movements

M. scorpius

Although relative positions in the study area were regularly recorded for the observed tagged fish, these data are not sensitive enough to determine the amount of daily swimming movement. Observations from day to day leave ample time for a particular fish to circulate freely about the study area and still return to the site of previous observation. Accordingly, a series of observation periods were planned over a 17 hour interval. Eight shorthorn sculpin were counted within this 17 hour interval. Four of these fish were seen more than once. The results of these observations are summarized in Table IV.

Table IV

Occurrance of tagged M. scorpius during night observations

Shorthorn Identity	Start of Observation Period				
	1540	2155	0219	0546	0840
877	+	-	-	+	-
135	+	+	+	+	+
138	+	-	+	+	-
132	-	-	-	+	+
783	+	-	-	-	-
110	+	-	-	-	-
804	-	-	-	+	-
001	-	-	-	+	-

Of the four shorthorns that were seen only once during this series of observations, three were never seen again during any observation period. One (804) was seen several times thereafter. Of the four seen more than once, two were seen several times thereafter while the other two were never seen again.

M. octodecemspinosus

The series of dives over 17 continuous hours was undertaken at a time when both species of sculpin were likely to be present in the area. The results of these dives pertinent to longhorn sculpin are presented in Table V.

Table V

Occurrance of tagged M. octodecemspinosus in Dyer's Gulch during night observations

Longhorn Idendity	*Start of Observation Period				
	1540	2155	0219	0546	0840
778	+	+	+	+	-
129	+	-	+	-	+
124	+	-	+	-	+
009	-	+	+	-	+
005	-	+	-	-	+
773	-	-	-	-	+
774	-	-	-	-	+
779	+	-	-	-	-
801	-	+	-	-	-
818	+	-	-	-	-
006	-	+	-	-	-
007	-	+	-	-	-
765	-	-	+	-	-

* On the date of these observations, sunset occurred at 2134 hours. Sunrise was at 0531 hours, local aparent time.

The amount of immigration into and emigration from Dyer's Gulch during this period suggests much activity for this species

throughout the night. Examination of Tables IV and V (summarized in Table VI) indicate that the shorthorn sculpin population in Dyer's Gulch is greatly reduced at dusk and increases again at dawn.

Table VI

Numbers of tagged sculpin counted in Dyer's Gulch during night observations

Species	Start of Observation Period				
	1540	2155	0219	0546	0840
Longhorn	5	6	5	1	6
Shorthorn	5	1	2	6	2

These data, however, may not be truly representative of the situation. At the time of these observations, large numbers of longhorn sculpin were immigrating into the area from their overwintering grounds. This resulted in large numbers of untagged sculpin in Dyer's Gulch. As observation times were restricted during all of these observation periods due to compliance with repetitive dive tables, only total numbers of sculpin were recorded. Within the tagged components of the two sculpin species present in Dyer's Gulch during the night, observations were precise as to species, position and tag number. In order to determine if the number of tagged sculpin was representative of the total Dyer's Gulch sculpin population, these data were analysed with a χ^2 (Table VII). Analysis between the number of untagged sculpin and the tagged sample indicates no significant difference between the two sets of data ($\chi^2=3.32$. $P=0.50$). Thus, the tagged sculpins of Dyer's

Gulch were indeed representative of the total sculpin population frequenting Dyer's Gulch throughout the 17 hour interval.

Table VII

Numbers of tagged and untagged sculpin seen in Dyer's Gulch during night observations

Component	Start of Observation Period				
	1540	2155	0219	0546	0840
Untagged	24	43	31	22	27
Tagged	10	7	7	7	8

Having determined the similarity of the tagged sample to the sculpin population of Dyer's Gulch, the two species of the tagged sample (Table VI) were compared with a χ^2 to assess their similarities. This analysis indicated that the two species of sculpin are different in their times of occupation of Dyer's Gulch (χ^2=9.48. P=0.05). Although the two species cannot be said to be mutually exclusive, their segregation in space at dawn and dusk is indicated.

Tagging

Attempts to determine the extent to which M. scorpius moves out into Logy Bay after occupying Dyer's Gulch were unsuccessful. Sonic tracking was unsuccessful largely due to unperfected technique. Sonic tags implanted in the stomachs were regurgitated within seven days when specimens were kept in the laboratory. In the field, tag retention was two to four days.

External attachment of the sonic tag proved to be far too conspicuous as several other sculpin were immediately attracted to

the transmitting fish and pursued it in an attempt to ingest the tag.

Of the shorthorn sculpin marked in Dyer's Gulch, one was seen outside the main study area. This single observation was of an adult in area E. At the time of observation, 144 days had passed since tagging. This specimen was observed twice previously, in Dyer's Gulch, two and three days after tagging.

The discussion of sonic tracking failures already applied to M. scorpius is also representative of the work attempted with the longhorns. A further complication with the longhorn is its smaller stomach and esophageal orifice relative to shorthorns of comparable length. It is possible that these morphological traits may have been associated with sonic tag regurgitation within four days. Surgical implantation of the sonic tag was undertaken in an attempt to prolong tag retention. The longhorn which was tagged surgically was found dead in site b four days after release. Death may have occurred as early as 30 hours after release. Inclement weather prevented tracking after this interval. The control specimen suffered no apparent ill effects for three weeks. At the end of this period the control specimen died, apparently because of a failure of the saltwater supply. It is not presently possible to objectively evaluate surgical technique as a means of affixing sonic tags. The procedure was abandoned in favor of the caplin technique previously described. Unfortunately, inclement weather combined with the fall emigration of longhorn from the study area did not allow evaluation of this latter technique.

The results of sonic tracking are too limited to be of analytical value. Of the sculpin for which several distinct positions were determined, only one left the study area. This fish was released at the surface in site c along with three other, externally marked, sculpin. Three of the four fish, including the sonic tagged specimen, were never seen again. The sonic tagged specimen was followed, from a boat, to a position approximately 200 metres seaward from Station #1. Three days later the sonic tag was recovered from the bottom at a depth of 16 metres. Heavy seas prevented tracking during this interval. No sculpin were seen in the vicinity of tag recovery.

Two sonic tagged specimens were monitered, on separate occasions, once every hour for 24 hours. Little movement was detected. However, one tag was found lying on the bottom in site d after 52 hours and the other specimen found dead in site b after four days.

Of the 28 shorthorn marked externally in other parts of Logy Bay, only one was observed in Dyer's Gulch. This single shorthorn was observed once. A total of 49 longhorn sculpin was marked in areas other than Dyer's Gulch. Three of these were subsequently observed in the main study area. Table VIII depicts the tagging done in areas other than Dyer's Gulch and the results.

An initial transplant of four shorthorns from site c to area C was not repeated due to poor rate of return to Dyer's Gulch. However, with time, three of the four subjects did return to the

study area, their times of absence being 2, 85 and 99 days. Of the five longhorn sculpin transplanted in the same experiment, none were ever seen again. Of the longhorn sculpin tagged in Dyer's Gulch, none were seen during dives in other areas. This, together with one tag return from five miles away, suggests that longhorn sculpin may move considerable distances.

Table VIII

External tagging of sculpin in areas peripheral to Dyer's Gulch

Date of tagging	Area	Shorthorn		Longhorn	
		Number tagged	Number entering Dyer's Gulch	Number tagged	Number entering Dyer's Gulch
May 15	F	2			
June 8	B	1		5	
June 29	A	10	1	5	
July 4	E	4			
July 10	B			2	
July 19	D	2		32	3
July 30	A	9		5	

P. americanus

Winter flounder have been observed on several occasions in the main study area. During the day, individuals of this species have varied in their behaviour from apparent complete inactivity (as determined by their lack of response for several seconds after being captured in a net) to extreme avoidance of divers. On the occasion of the 17 hour observation series on sculpin, a dense aggregation of more than 100 winter flounder was noted in the vicinity of station #1 at 2155 hours. These fish were compacted into such a small area that they were overlapping each other,

often three fish deep. More than 50% of these fish were in the feeding position described by Olla, et al, (1969). Several specimens were also observed swimming, slowly, approximately two to three metres above the bottom. At the time of these observations, ambient light intensity was great enough that the water surface could be seen from a depth of 18 metres. However, to the human eye, the bottom was completely dark and had to be artificially illuminated. The restriction on observation duration during this dive series did not permit investigation of the flounder activities. It is likely that, by this date (June 26) the height of the spawning season was over as few gravid females were seen in late June.

Affinity for Dyer's Gulch

The affinity of the two sculpin species for Dyer's Gulch is most easily described on a comparative basis. A t-test of the number of sculpin seen within three days of tagging (longhorn vs. shorthorn, Table IX) relative to the total numbers tagged (with arcsin transformation) indicates no difference between the affinities of the respective species for Dyer's Gulch immediately subsequent to tagging ($t=0.68$, $P=0.52$). The same type of analysis of the shorthorns never seen again and these data for the longhorns (Table X) suggests no difference between the affinities of the two species for Dyer's Gulch ($t=0.97$. $P=0.37$) or that their rates of mortality are similar subsequent to tagging.

The data of Table XI suggest that shorthorn return to Dyer's Gulch more frequently than longhorns. As the number of longhorn

Table IX

Affinities of sculpin for Dyer's Gulch after tagging

Date	Number of Shorthorn tagged	Number seen within three days	Ratio	Number of Longhorn tagged	Number seen within three days	Ratio
1972						
Aug.	3	1	0.33	42	10	0.24
Sept.	1	0	0.00	1	0	0.00
Oct.	16	3	0.19	3	0	0.00
1973						
May	24	2	0.08	12	3	0.25
June	28	8	0.29	80	31	0.34
July	18	8	0.44	69	35	0.51
Sept.	3	0	0.00	3	2	0.67

was far greater than the number of shorthorn tagged during this study, the results of Table XI are likely biased in favor of the longhorns. It is therefore concluded that M. scorpius shows a greater affinity for Dyer's Gulch than longhorn sculpin.

Table X

Numbers of sculpin not observed subsequent to tagging

Date	Number of Shorthorn tagged	Number never seen again	Ratio	Number of Longhorn tagged	Number never seen again	Ratio
1972						
Aug.	3	1	0.33	42	18	0.43
Sept.	1	0	0.00	1	0	0.00
Oct.	16	7	0.44	3	2	0.67
1973						
May	24	10	0.42	12	9	0.75
June	28	12	0.43	80	40	0.50
July	18	10	0.56	69	21	0.30
Sept.	3	1	0.33	3	1	0.33

Table XI

Fish returning to Dyer's Gulch more than nine months after tagging

Species	Date Tagged (1972)	Number of Sightings	Last Sighting (1973)	Days at large
Shorthorn	Sept. 22	5	Oct. 31	402
	Oct. 12	13	Nov. 26	379
	Oct. 12	6	July 23	284
	Oct. 18	15	Nov. 9	387
	Oct. 18	2	July 18	273
	Oct. 24	3	Oct. 26	367
Longhorn	Aug. 10	5	July 13	338
	Aug. 11	3	Aug. 8	362
	Aug. 15	2	July 11	330
	Aug. 15	2	July 20	339
Winter Flounder	Aug. 15	1	July 6	325
	Aug. 31	4	July 6	309
	Sept. 26	3	July 11	278
Yellowtail	Aug. 9	4	July 27	353

The percentage of sculpin tagged each month that is never seen again varies considerably with date of tagging (Fig. IV). The greatest rate of disappearance for the longhorn is in the spring while that for the shorthorn is in the summer.

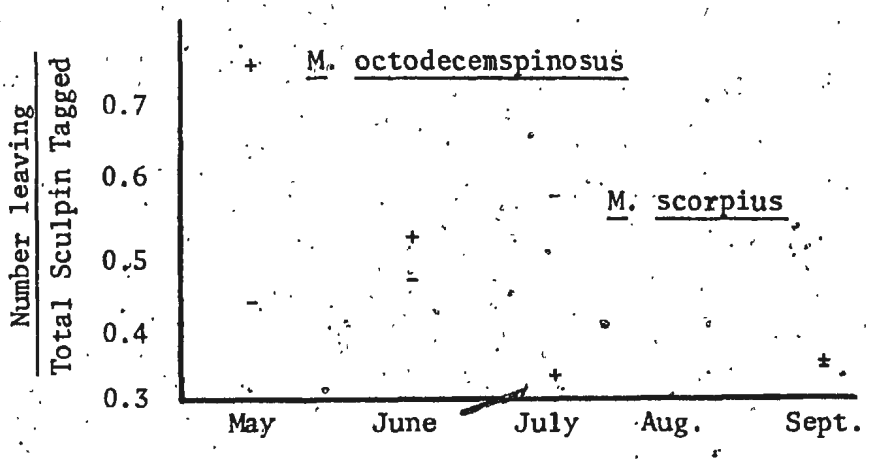


Figure IV. Disappearance of sculpin from Dyer's Gulch

P. americanus

Of 36 winter flounder tagged in Dyer's Gulch, 16 were observed subsequent to tagging. Seven of these 16 fish were observed in Dyer's Gulch more than six months after tagging. This figure is lower than it should be as several other tagged flounder were noted in the area on various occasions but could not be identified. The greater aversion to a diver shown by winter flounder than by the two species of sculpin necessitates coded tags which can be identified from at least one metre away. The thin dorsal musculature and greater swimming ability of flounder over sculpin also results in greater tag loss and possibly mortality. Specimens have been found with wounds which indicated that tags had been lost.

S. punctatus

In early August, 1973, eleven adult S. punctatus were collected in the vicinity of station #2. These fish were anaesthetised with MS222 and tagged in the laboratory by sewing glass beads (1 mm. diameter) to the anterior, dorsal musculature. No abnormal fish were observed among the tagged specimens for ten days following tagging. After this interval, the tagged specimens were released at the bottom in the area of capture.

Of these eleven fish, five were observed subsequent to release. Four of these exhibited fidelity to the area of capture-release. The fifth fish was observed once in the vicinity of station #1. An adult S. punctatus which bore definite tagging wounds but no tag was observed at station #1 on August 29, 1973. It did not appear

to be weakened by its wound.

Quantitative Analysis of Site Association

Of the seven benthic species included in the multiple regression analysis, models have been derived for only three species: M. scorpius, M. octodecemspinosus, and Stichaeus punctatus. Correlation matricies (Appendices III and IV) imply possible relations among the other variates.

As data on species distributions in sites a and c have indicated a greater abundance of most benthic fish species in site c, one model is presented for each species for each site.

The presence of several sub-zero temperature readings in the data matrices made natural logarithm linearity transformations impossible. Accordingly a constant of 2.0 has been added to all independent variates thereby displacing the regression on the x-axis to positive values. This constant must be included with each independent variable when using the equations as prediction models.

All independent variables are significant ($P < 0.05$) in their contribution to the models. Independent variables are included in the equations in decreasing order of importance.

The following definitions apply to all equations:

x_2= number of shorthorn in site a + 2.0

x_4= number of shorthorn in site c + 2.0

x_5= mean number of S. punctatus per square metre in site a + 2.0

x_6= mean number of L. atlanticus per square metre in site c + 2.0

x_7= mean number of young M. americanus per square metre in site designated by dependent variable + 2.0

x_8= mean number of young U. subbifurcata per square metre in site designated by dependent variable + 2.0

x_9= mean number of young sculpin per square metre in site c + 2.0

x_{10}= water movement code + 2.0

x_{11}= temperature in degrees Centigrade + 2.0

x_{12}= mean radiant energy influx per site + 2.0

x_{13}= photoperiod + 2.0

Having defined these parameters, it is now possible to describe the models.

The number of shorthorn sculpin to be found in site a at any one time is:

$$Y = -5.13117 + 2.00004 \log_e x_{13} + 0.31115 \log_e x_{10} - 0.45912 \log_e x_5 \quad \ldots\ldots(1)$$

For this equation, the multiple correlation coefficient is low, the overall equation accounting for only 9% of the variability in the number of shorthorn in site a. This model is thus inadequate.

The number of shorthorn to be found in site c at any one time is:

$$Y = 4.97382 - 1.45069 \log_e x_{13} - 0.19402 \log_e x_{11} + 0.29617 \log_e x_{10} + 0.69107 \log_e x_7 - 0.88015 \log_e x_8 \quad \ldots\ldots(2)$$

The correlation coefficient is again insignificant (R=0.346. P >0.05), the equation accounting for 11.97% of the total variability in Y.

The model for longhorn sculpin in site a is:

$$Y = -13.03613 + 3.32782 \log_e x_{13} + 1.30076 \log_e x_{11} - 2.09695 \log_e x_{10} + 3.22689 \log_e x_2 + 0.89735 \log_e x_{12} \quad \ldots\ldots\ldots\ldots(3)$$

The multiple correlation coefficient (R=0.547. P< 0.01) credits the equation with 29.92% of the variability in Y. However, the table of residuals (deviations of calculated Y values from observed values) indicates an inaccurate model.

The number of longhorns in site c is described by:

$$Y = -22.30298 + 8.32712 \log_e x_{13} + 0.86414 \log_e x_{11} - 1.68085 \log_e x_7 + 0.96683 \log_e x_4 \quad \ldots\ldots\ldots\ldots(4)$$

This model accounts for 39.56% of the variability in Y (R=0.629. P< 0.01). The table of residuals indicates compliance with the model (deviations of less than 1.0) in about 43% of cases.

The number of S. punctatus per square metre in site a is given as:

$$Y = 0.29867 + 0.27519 \log_e x_{11} - 0.42607 \log_e x_2 \quad \ldots\ldots\ldots\ldots(5)$$

The variability in Y accounted for by this equation is 13.54% (R=0.368. P< 0.01). Again the model, although representative in 87% of cases, is unsuitable. Deviations of up to 80% from the higher of the observed Y values make this model unreliable.

The number of S. punctatus per square metre in site c is given by:

$$Y = 0.70556 + 0.23818 \log_e x_{11} - 0.49660 \log_e x_7 - 0.38436 \log_e x_9 \quad \ldots(6)$$

This equation accounts for 17.39% of the variability in Y (R=0.417. P< 0.01). Deviation of the estimated Y from the observed values of more than 1.0 occurred in 7% of cases. Again deviation was greatest for the highest observed values of Y.

Food and Feeding

Shorthorn stomach contents obtained in May were, in quantity, several times greater than those obtained in any other month. The May samples were the only ones in which significant numbers of fish remains were found. One specimen contained thirteen whole adult sea snails, eleven intact vertebral columns, likely of L. atlanticus, more than 100 polychaetes plus several scale worms (Lepidonotus sp.) and amphipods. No food items were regurgitated in the fall although the emetic was administered to several specimens.

The extreme numbers of particular prey species which have been found in shorthorn stomachs at certain times suggests that M. scorpius is efficient in its utilization of aggregations of prey species. On several occasions, especially during late spring, shorthorn sculpin were seen which had greatly distended abdomens. The food of the shorthorn sculpin is determined apparently by whatever is most abundant and most easily obtained.

In the laboratory, shorthorn sculpin have been observed to eat several caplin (Mallotus villosus) in one feeding session and have been noted to capture and consume live cunners (Tautogolabrus

adspersus) when the two species have been kept in the same holding tanks. On one occasion a female shorthorn (400 mm. total length) was observed, in this lab situation, to completely swallow a temporarily incapacitated cunner of about 150 mm. fork length. Shortly thereafter, the same sculpin took another, somewhat smaller cunner. Although this exact situation is unlikely to occur in the field, it demonstrates the gastronomic capacity of the shorthorn.

M. octodecemspinosus

Attempts to induce regurgitation of food from longhorns were largely unsuccessful. The only food found in Dyer's Gulch longhorns were crabs (Hyas sp.), amphipods and caplin (Mallotus villosus). Out of fifteen longhorns treated with the emetic, only three regurgitated food. To test the effectiveness of the emetic, the stomachs of four longhorns (on separate occasions) were examined after there had been no response to the emetic. These specimens were chosen because of their engorged appearance. All four stomachs were found to be empty. It is therefore possible that the longhorns had been feeding on soft bodied forms that were digested quickly or that they were eating very little. The common presence of Nereis sp. among the shorthorn stomach contents tends to negate the first possibility.

Subsequent to feeding on animals with hard body parts, such as large crustaceans, the presence of the exoskeleton in the longhorn stomach is readily detectable by touch. During the various tagging

periods, hard materials were rarely detected in the stomachs of longhorns although such occurrance was more common among M. scorpius stomachs. Seasonal variation in the amount of food consumed could not be determined for the longhorn sculpin due to the described difficulties. Further intensive investigation would be necessary in order to quantify longhorn feeding habits (Jenkins, M.Sc, in preparation).

Predators

Juvenile sculpin (less than 70 mm. - unidentified to species) have been noted among the stomach contents of the adults. The young have also been observed to prey on each other in the lab whenever size difference allowed ingestion.

Within the main study area, only one other benthic species could, on the basis of size and morphology, serve as a predator on shorthorn sculpin. The sea raven, H. americanus, has the morphological capacity to consume prey as large as sculpin. Cannabalism within this species has been documented in the laboratory. In this instance, an adult female consumed another raven of about 200 mm. total length (Bennett, pers. comm.).

Unfortunately, H. americanus did not respond to the emetic. Attempts to induce regurgitation with a stomach pump (designed by Seaburg and Moyle, 1964) also failed. As there were never more than eight specimens seen at any one observation period, no individuals were sacrificed.

A qualitative investigation of possible controlling mechanisms

for the shorthorn population implicated the leech, Malmiana nuda Richardson (1970).

Observations of shorthorn sculpin carrying several leeches were common. Infestation of individuals ranged from zero to high concentrations of more than 15 leeches per host. Leeches were seen most commonly between the eyes of the sculpin and on the nasal area. No sculpins were seen bearing leeches during the winter.

The higher affinity of shorthorn over longhorn sculpin for rock bounded hiding places may account for the greater infestation of shorthorns by leeches. As the newly hatched leeches depend, for their attachment, on the movements of potential hosts, species regularly inhabiting such areas are highly susceptible to attack. Although densities of leeches on individual longhorns were at least as great as on M. scorpius, the infestation is less (on a percentage basis) than that of M. scorpius (Khan, in preparation).

The presence of several young cod (Gadus morhua) in Dyer's Gulch in August and September of both study years suggested the possibility that this species may have been feeding on arctic shanny. Of 22 cod caught in the study area in late October, 1973, only 10 had recently taken food. With the exception of one juvenile sculpin, stomach contents were invariably amphipods:

DISCUSSION

The general approach in this study was to first determine the distribution and abundance of benthic fish in a finite and accessable area, then to attempt to determine whether the area was, in effect, one continuous habitat or composed of smaller subdivisions. Having found such subdivisions, the final question is, why such divisions are found among the shallow water benthic fish community?

In following this approach, an attempt has been made to avoid, as much as possible, making assumptions about the data. Accordingly, the analysis of χ^2, with its minimal assumptions, has been used extensively. The t-test is a special case of the analysis of variance (Bancroft, 1965) and requires approximate normality of population distribution and similar standard deviations. The analysis of variance is a more robust test which, in its simplest interpretation, allows comparison of more than two means. Having once exhausted the capacity of these more common tests, I have attempted to indicate what factors may contribute to the variability in the numbers of sculpin by the technique of multiple linear regression. This test has also minimized assumptions about the data by mathematical transformations for linearity and normality (Cassie, 1972).

Distribution and Abundance of Myoxocephalus in Dyer's Gulch

In determining whether significant differences in the distribution of sculpin occur throughout the study area, two questions must be asked. First, are there differences in the numbers of fish throughout the study area or is the area equally suited to the species under consideration

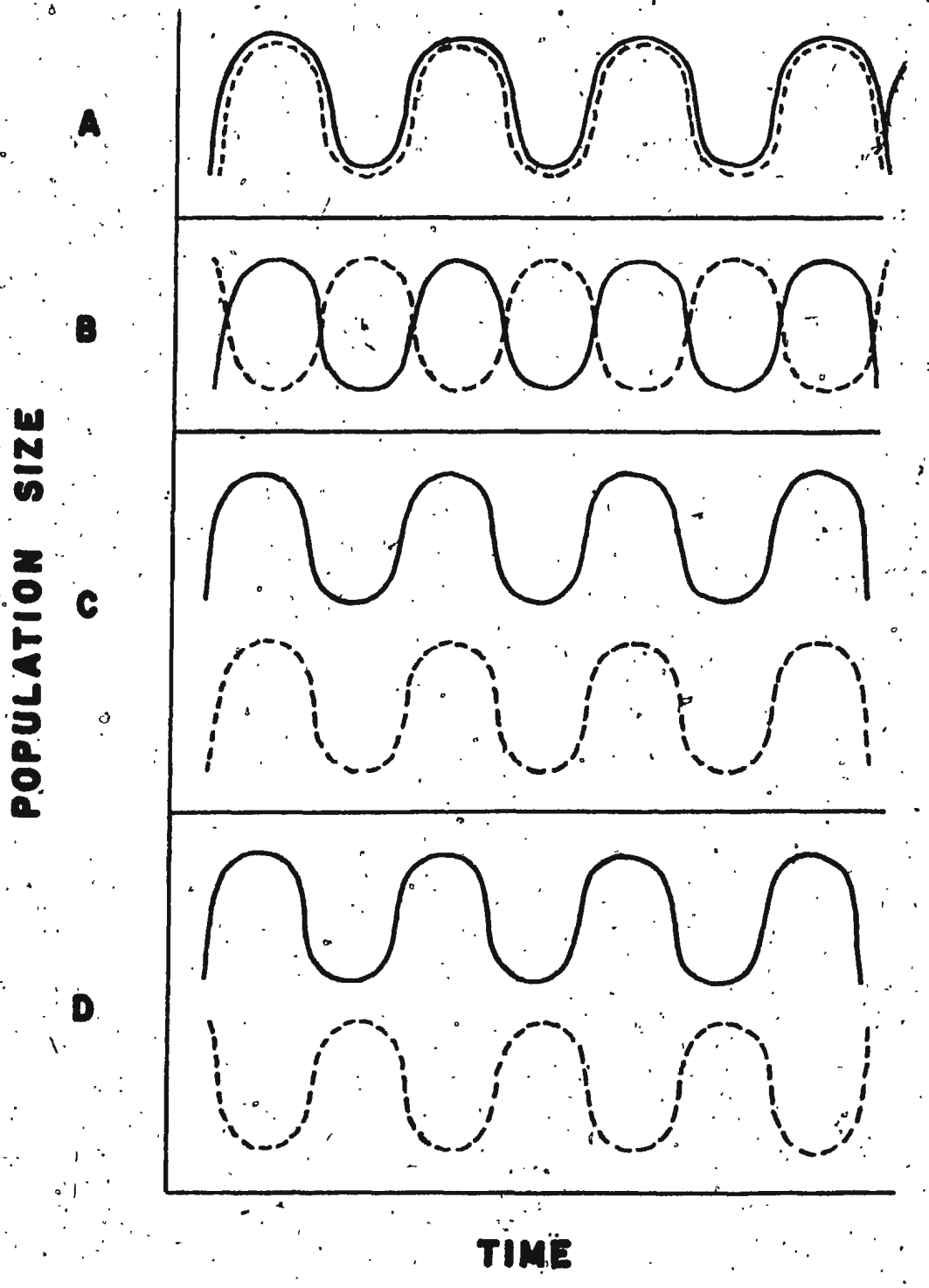


Figure V. Possible combinations of fluctuations around the mean for two populations

(random or contagious distributions)? A second question that should be asked is, does an increase (or decrease) in the number of fish in one subdivision of the study area correspond with an increase (or decrease) in the number of fish in another such subdivision? In other words, do fluctuations around the individual population means correspond in their times of relative maxima and minima? The possible outcomes of these two questions are represented in Fig. V. The results of analyses of shorthorn data indicate a correspondence with situation D (Fig. V), in that the means are different for the two sites and that fluctuations around the means do not correspond in time. This is likely caused by preference for site c which may be reflective of their lethargic and cryptic habits. Site a is separated from site b by a sudden increase in depth of approximately three metres. The barrier here is vertical for most of the width of the gulch. A narrow "shute" on the southeast side of the gulch is inclined at an angle of about 45 degrees. If fish are to avoid swimming in the water column, they would have to move up this unprotected shute to site a. The hypothesis here is that shorthorn sculpin would prefer to swim around rather than over an obstruction. This, combined with the scarcity of cover may act to confine most of the shorthorns to the lower regions of the gulch.

The longhorn sculpin distribution data correspond with situation B (Fig. V). This would suggest free interchange of longhorn between the two sites with simultaneous immigration (and emigration) to the whole study area. Interchange of individual longhorn between the two sites is likely facilitated by their lower affinity for cover

and their greater locomotory tendency. For such an animal, the rock barrier is possibly ineffective.

On the basis of length-weight data for longhorn (Morrow, 1951) and shorthorn (Ennis, 1970) plus morphological descriptions of the two species (Liem and Scott, 1966), the apparent difference in mobility between the two species may have a hydrodynamic basis. Such a difference in swimming ability could result in longhorns moving further from Dyer's Gulch, thus reducing their chances of being observed again. Their low rate of return to Dyer's Gulch after extended periods (Table XI) plus a longhorn tag return from a distance of five miles, supports this hypothesis. Differences in swimming activity between sculpin species may also be of significance in the differential infestation of the two species by the leech, the less active shorthorn being more attractive for attachment.

Predators

The greater infestation of shorthorn by M. nuda may be due to a combination of the behaviour of adult shorthorn and the life history of the leech.

Most commonly, the Piscicolidae detach from their hosts before copulation occurs. This however, does not appear to be the case with M. nuda as copulatory behaviour of attached leeches has been observed (Khan, pers. comm.). Subsequent to fertilization, the cocoons are attached to rocks where the cocoons develop and hatch. As the cocoon was deposited while the adult leech was still

attached to its host, the young leech is likely to be in suitable shorthorn habitat. The lethargic habits of the shorthorn would be condusive to attachment. Longhorns, if as active as this research suggests, would be more likely to occupy areas which are unsuitable for leech cocoon attachment, such as sandy bottoms.

Prior to taking a blood meal, M. nuda secretes what is likely an anticoagulant. It is known (Khan, pers. comm.) that ten of these leeches are detrimental to small sculpin (less than 10 cm.). Adults which have been artificially heavily infested in laboratory holding tanks have become sluggish relative to uninfested specimens and have been generally less successful in securing food.

Mace (1971) states that M. nuda is most commonly found on shorthorn sculpin in the opercular region and on the belly. He states that this leech is found on the head of M. scorpius only on heavily infested individuals. As leeches were most commonly seen on the head region of sculpin in the present study, it may be that Dyer's Gulch shorthorn suffer heavy parasite loads. Mace also determined that parasitised shorthorn had a higher metabolic rate than unparasitised individuals. He indicates that the increased energy expenditure among parasitised fish is greater than can be accounted for by blood loss to the leech and suggests stress caused by mechanical irritation may be detrimental. On the basis of his findings, Mace evaluates the leech-sculpin relation as predatory rather than parasitic.

Seasonal Occurrance

The change in affinity for cover in the winter shown by

M. scorpius is likely of survival value to newly spawned eggs. Egg masses situated in open areas may receive the benefit of greater water circulation than if they were recessed in crevices in the bottom. It is interesting to speculate that the shorthorns are able to become less secretive in winter due to the absence of longhorns in the area.

As implied above, M. scorpius apparently has the capacity to comsume more food at any one opportunity than the longhorn. This may have survival value for the shorthorn when presented with a situation where food is clumped and scarce. Without quantitative data on seasonal abundance of prey species, it is impossible to determine if food is limiting during the winter months.

A hypothesis to account for the absence of M. octodecemspinosus in the winter is that, Dyer's Gulch and vicinity does not contain suitable spawning substrate for the longhorn. Warfel and Merriman (1944) reported that eggs of longhorn sculpin of southern New England were found attached to sponge (Chalina sp.). Although this genus is found in Dyer's Gulch, the hard sand and gravel bottoms described by Warfel and Merriman are less common.

Incubation Activity

The spawning success of the shorthorn in Dyer's Gulch in 1973, being zero, is contradictory to the number of young sculpin found in the area in the summer of the same year. Since the number of young-of-the-year sculpin (based on Ennis (1970) Age 1 fish of minimum length of 11.4 cm.) per square metre in Dyer's Gulch in

1973 was greater than ever documented previously (Green, pers. comm:), the extensive egg mortality found in Dyer's Gulch cannot be representative of the eastern Newfoundland coast.

Ennis (1970) observed that guardian sculpin (always males) vacated the nests for varying periods. Therefore the observed behaviour of the Dyer's Gulch fish is not unusual.

Although shorthorn sculpin have physiological means of protection from freezing in very cold waters (Gordon, et. al., 1962; Smith, 1972), their survival depends on their avoidance of contact with ice crystals. The winter of 1972-73 was unusual in that great quantities of ice built up along the Newfoundland coast. In Logy Bay, onshore winds jammed ice blocks on top of each other to depths of more than 23 metres. It is possible that such conditions forced the shorthorns of Dyer's Gulch to abandon their eggs.

Segregation and Cohabitation

Harper (1961) states that cohabitation is a situation where "individuals come into such proximity that a struggle for existence is likely to occur.". He goes on to suggest that an interspecific equilibrium is facilitated by a "division of labour".

The percentage of fish tagged each month that is never seen again (Fig. IV) indicates that the two species of sculpin have changing affinity for Dyer's Gulch throughout the period of cohabitation. The apparent divergence of the two curves of Fig. IV suggests that the two species may indeed have some "division of

labour" or perhaps interspecific avoidance.

The results of the 17 hour series of dives cannot be accepted as being representative due to the lack of replicate series. However, the trend described by the data warrants future investigation and further discussion.

The obvious difference between the abundance of the sculpin species at dusk and dawn suggests either that there is a particular attraction for Dyer's Gulch (more accurately, site c) at these times or that the attraction is for some peripheral area and that movement back to Dyer's Gulch occurs with the opposite stimulus (increasing or decreasing radiant energy influx). Whether such movements are related to food or changing site preference is unknown. Green (pers. comm.) has shown that cunner (Tautogolabrus adspersus) occupy "sleep sites" at night but may occupy a completely different territory during the day. Reciprocal movements of the two species of sculpin could serve to reduce interspecific interactions. Further investigation of this phenomenon is necessary before any conclusions can be reached.

Another question pertinant to the two sculpin species is that of the difference in population sizes. Why should there be so many more longhorns than shorthorns in the study area? The secretive habits and restricted movements of M. scorpius suggest that this species may have a large individual distance (defined by Hediger. In Lorenz, 1963). Although agonistic interactions have not been noted in the field, sculpin of both species have been found

to emit a vibration when removed from the water. This vibration is audible when the individual is pressed against a measuring board. A similar type of response has been documented by Bigelow and Welsh (1925) and analysed by Barber and Mawbry (1956). Visual detection of this behaviour in the field has been facilitated by the anchor tags which have been noted to vibrate rapidly when individual sculpin are approached by a diver. If this is a warning, it could serve to space animals over suitable habitat. In such a situation, population control could be behavioural. Fish (1954) states this vibration is made in response to fear and annoyance. Controlled laboratory studies would be beneficial in determining inter- and intraspecific behavioural interactions.

Pleuronectids

Although P. americanus received little attention throughout the period of the present study, it was, occasionally, more numerous than the longhorn sculpin. Although less common in Dyer's Gulch, the yellowtail was often found concurrently with winter flounder. The interactions between these two species could constitute an interesting study. The American plaice, Hippoglossoides platessoides, was observed concurrently with both winter flounder and yellowtail on the sandy bottom of area B. The niche diversification theoretically necessary for persistence of this situation could be pertinant to commercial exploitation of these species.

The method of tagging used in the present study is considered

inadequate for study of the flounder and yellowtail (see winter flounder results). Use of a shorter dart tag (possibly 30 mm. long) might possibly reduce vibration caused wound enlargement.

Of interest in literature on winter flounder is the variability in their onshore-offshore movements from one locality to another (Lobell, 1939; McCracken, 1963; Kennedy, 1964). Kennedy (1964) suggests such movements may be governed by the state of the gonad rather than temperature. It is unknown if the gravid females seen in Dyer's Gulch in the spring of 1973 spawned in the area or not.

Sonic Tracking

The inadequacy of studies, of fish movements, based on periodic observations has been exemplified in the present research. The need for continuous monitoring of movements of individual fish could be satisfied by sonic tracking techniques. Although pelagic species have been successfully followed by use of sonic tags (reviewed by Stasko, 1971) benthic species showing restricted movements could likely provide more extensive data. This could be accomplished by a fixed monitoring system.

Quantitative Analysis of Site Association.

Gibson (1972) used a multiple correlation analysis to evaluate factors influencing the vertical distribution of some intertidal fish species. He did not, however, present models to describe the abundance of the individual species. This may have been due to a low multiple correlation coefficient.

The general inadequacy of the prediction models of the present

study may be attributed to several factors. At least one of these may be tested with the present data. The inclusion of a great number of zeros in the data tends to make the equations most accurate only for those values of the dependent variable which approach zero. This hypothesis may be tested by decreasing the time interval for which any one equation is to be applied. By limiting the time interval to that period in which the species of interest (dependent variable) is present, the great preponderance of zero observations can be avoided.

These models may be greatly improved in future studies by refining the techniques used in obtaining environmental data. The indirect measurement of random water movements does not permit comparison of the various study sites with respect to this parameter.

The extinction coefficient used in calculating radiant energy influx at the various stations is greatly deficient. This is especially pronounced during periods of heavy rainfall when the surface waters of Dyer's Gulch become markedly discolored by suspended soil particles washed into the gulch from the surrounding watershed. This problem could be overcome by regular (daily if possible) determinations of the extinction coefficient.

The inclusion of biotic parameters among the independent variables of the models cannot be explained by field observations of this research. Although the multiple regression formulae indicate these biotic parameters contribute less to the equations than the abiotic parameters, their significance ($P < 0.05$) in

reducing the error in the dependent variable estimate warrants future investigation of these parameters. No interactions among species were observed except for occasional, unsuccessful, attacks of longhorn sculpin on smaller fish species. Witnessed longhorn attacks on pieces of debris, animated by water movements, suggests movement will ellicit predation responses for this species. However, the non occurrance of all but one of the smaller species among stomach contents of both species of sculpin suggests sculpin are not effective predators on other benthic fish species. This is supported by laboratory experiments (Jenkins, M.Sc. thesis, in preparation).

The fact that individual shorthorn sculpin will ingest large numbers of sea snails has been shown in this study. This is possibly due to the poor swimming ability of the sea snail and its corresponding vulnerability whenever it emerges from the undersides of rocks. In spite of this known predation, the numbers of L. atlanticus per square metre did not contribute to the shorthorn models (equations 1 and 2).

Many of the relations found in these models, such as the negative correlations of S. punctatus with shorthorn in equation 1, of U. subbifurcata with shorthorn in equation 2 and U. subbifurcata with S. punctatus in equation 5 cannot be explained by the present data. Such correlations warrant future studies both of laboratory and field orientation.

LITERATURE CITED

Bancroft, H. 1965. Introduction to Biostatistics. New York. Hoeber Medical Division. Harper and Row.

Barber, S.B. and W.H. Mowbray. 1956. Mechanism of sound production in the sculpin. Science. 124(3214): 219-220.

Bigelow, H.B. and W.W. Welsh. 1925. Fishes of the Gulf of Maine. Bull. U.S. Bur. Fish. (1924), 40(1): 1-567.

Carstens, T. 1968. Wave forces on boundaries and submurged bodies. Sarsia, 34: 37-60.

Cassie, R.M. 1972. A computer programme for multivariate statistical analysis of ecological data. J. exp. mar. Biol. Ecol. 10: 207-214.

Clarke, G.L. and E.J. Denton. 1962. Light and animal life. In, The Sea. Volume I. pp. 456-468.

Ennis, G.P. 1970. The biology of the shorthorn sculpin (Myoxocephalus scorpius L.) in Newfoundland waters. M.Sc. thesis, Memorial University of Newfoundland. 71 p.

Farwell, M.K. 1971. The agonistic behaviour of juvenile Stichaeus punctatus. M.Sc. thesis, Memorial University of Newfoundland. 104 p.

Fish, M.P. 1954. The character and significance of sound production among fishes of the Western North Atlantic. Bull. Bing. Ocean. Coll. 14(3): 109 p.

Gibson, R.N. 1972. The vertical distribution and feeding relationships of intertidal fish on the Atlantic coast of France. J. Anim. Ecol. 41(1): 189-207.

Gordon, M.S., B.H. Amdur and P.F. Scholander. 1962. Freezing resistance in some northern fishes. Biol. Bull. Woods Hole. 122: 52-62.

Harper, J.L. 1961. The evolution and ecology of closely related species living in the same area. Evolution. 15: 209-227.

Himmelman, J.H. 1969. Some aspects of the ecology of Strongylocentrotus droebachiensis in Eastern Newfoundland. M.Sc. thesis, Memorial University of Newfoundland. 159 p.

Kennedy, V.S. 1964. Aspects of the biology of the winter flounder, Pseudopleuronectes americanus (Walbaum), in Long Pond, Conception Bay, Newfoundland. M.Sc. thesis, Memorial University of Newfoundland. 113 p.

Liem, A.H. and W.B. Scott. 1966. Fishes of the Atlantic Coast of Canada. Fish. Res. Bd. Canada. Bull. 155, 485 p.

Lobell, M.J. 1939. A biological survey of the salt waters of Long Island, 1938. Report on certain fishes. Winter flounder (Pseudopleuronectes americanus). Suppl to 28th. Ann. Rept. N.Y. State Conserv. Dept., Pt. I: 63-96.

Lorenz, K. 1963. On Agression. Harcourt, Brace and World, Inc.

Mace, T.F. 1971. Energetics of a host-parasite relationship as illustrated by the leech Malmiana nuda, Richardson and the shorthorn sculpin Myoxocephalus scorpius (L.). M.Sc. thesis, Memorial University of Newfoundland. 68 p.

Markus, H.C. 1932. The extent to which temperature changes influence food consumption in largemouth bass (Huro floridana). Trans. Am. Fish. Soc. 62: 202-210.

McCracken, F.D. 1963. Seasonal movements of the winter flounder, Pseudopleuronectes americanus (Walbaum), on the Atlantic Coast. J. Fish. Res. Bd. Canada. 20(2): 551-586.

Morrow, J.E. Jr. 1951. Studies on the marine resources of southern New England. VIII. The biology of the longhorn sculpin, Myoxocephalus octodecemspinosus Mitchill, with a discussion of the southern New England "Trash" fishery. Bull. Bing. Ocean. Coll. 13(2): 89 p.

Olla, B.L., R. Wicklund and S. Wilk. 1969. Behavior of winter flounder in a natural habitat. Trans. Am. Fish. Soc. 98 (4): 717-720.

Paine, R.T. 1966. Food web complexity and species diversity. Am. Naturalist. 100: 65-75.

Richardson, L.R. 1970. A new marine piscicolid leech from Newfoundland placed provisionally in the genus Malmiana. Can. J. Zool. 48(4): 841-845.

Sanders, H.L. 1968. Marine benthic diversity: a comparative study. Am. Naturalist. 102: 243-282.

Seaburg, K.G. and J.B. Moyle. 1964. Feeding habits, digestive rates and growth of some Minnesota warm water fishes. Trans. Am. Fish. Soc. 93(3): 269-285.

Smith, R.N. 1972. The freezing resistance of Antarctic fish. III. An experimental study of the death of supercooled fish resulting from contact with ice. British Antarctic Bull. No. 3. October.

Stasko, A.B. 1971. Review of field studies on fish orientation. Ann. N.Y. Acad. Sci. 1(88); 12-29.

_____ and S.M. Polar. 1972. Do-It-Yourself Hydrophone. Fish. Res. Bd. Canada, St. Andrews, New Brunswick. Underwater Telemetry Newsletter. 2(1): 15-17.

Traversy, W.J. 1971. Some methods of water analysis. Water Chemistry Subdivision, Water Quality Division, Department of Fisheries and Forestry. Ottawa.

Warfel, H.E. and D. Merriman. 1944. The spawning habits, eggs and larvae of the Sea Raven, Hemitripterus americanus, in Southern New England. Bull. Bing. Ocean. Coll.

APPENDIX I

Numbers of "smaller species" Per Quadrat

Species	Site a																Site c															
	Arctic Shanny				Sea Snail				Ocean Pout				Radiated Shanny				Young Sculpin				Arctic Shanny				Sea Snail				Ocean Pout			
Quadrat	7	8	9	10	7	8	9	10	7	8	9	10	7	8	9	10	7	8	9	10	2	3	4	5	2	3	4	5	2	3	4	5
1972																																
Aug. 4	6	3	10	12																			3				1	1				
Aug. 22	7	3	9	6								2										1	2	5				1				
Aug. 28	5	6	8	4								4				5																
Sept. 21	9	9	7	7						1						2					1	4	6	5								
1973																																
Feb. 27																						1		3	1					1		
March 5		1													1											2		1		1	1		
March 12						1		1														1		1	1						1	
March 20						1	1	2														1	1	3								
April 12			1												1										5				1		1	
April 17																									1	1						
April 24							1	2													1				1	4	1	2				1
May 9								1						1																		
May 15						1								1	1	1									1	1	1					
May 22						1				1															1		1	1	1			1
May 30									1	2														2			2	1	2			
June 6						1	2		1							1											1		1	3			
June 12									1	2											1	1				1				1	1		
June 28																					1						1	1		1	1		
July 5		1													1						1							2	1			1	
July 11														1	1							1			1		2		1			2	
July 18												1										1				1		2		1			1
July 25												1				1						2					1			1			1
Aug. 3	4	3		2								1											1			1		1		1			3
Aug. 8	2		1									1		1	1	1											1			1		
Aug. 29		2								1			1			1			2			1	2									1
Sept. 13																2			1			1								3		1	
Sept. 19	2			2											1	1							2	1					1	1	1	1	2
Sept. 28		2	1	1								1						2			1		1	3							1	1
Oct. 3	1	1	2	5																	1										2	1
Oct. 24				1				1				1			1								1			1			1	1	1	1
Oct. 31		1		1								1	1										1							1		
Nov. 7		1																					1							1		
Nov. 16																							1					1		2		
Nov. 29		1																			1											
Dec. 7		1																											1		1	
Dec. 12															1								1					1			2	
Dec. 20																		1	1			1	1						1		1	

APPENDIX II

Numbers of "larger species" seen per dive *

Date	Shorthorn	Longhorn	Untagged Sculpin	Winter Flounder	Yellowtail	Sea Raven	Ocean Pout
1972							
July 25	1	3					
July 27		3					
July 28		1					
Aug. 9	2	5			1		4
Aug. 10		14		4	1	1	
Aug. 11	1	7		5			
Aug. 14	3	10					
Aug. 15		8		6	1		1
Aug. 17		2					
Aug. 18		5					
Aug. 22		3					
Aug. 23		9		1	1		1
Aug. 24		4					
Aug. 25		3		1	1		
Aug. 29	1	5		4		1	
Aug. 31				3			
Sept. 5		2		1			
Sept. 6		3	1				
Sept. 12		4	2	2			
Sept. 13		1		1			
Sept. 14		2					
Sept. 21		2		2		2	
Sept. 22	1	3		2			
Sept. 26		1		1			
Oct. 5					1	1	
Oct. 6	2						
Oct. 12	6				1		
Oct. 16	2	1					
Oct. 17		1					
Oct. 18	4	1		1		1	
Oct. 20		1					
Oct. 23	5	3		1		2	1
Oct. 24	8	3				3	1
Oct. 27	1						
Nov. 1	1	1					1
Nov. 2	1						
Nov. 3	1						
Nov. 6	1	1					
Nov. 17	4	1					
Nov. 27	1	1					
Nov. 28	1						
Nov. 29	4		3				
Nov. 30	8						1
Dec. 8	2						
Dec. 22	1						
Dec. 28	1						
1973							
Jan. 4	1						
Jan. 8	2						
Jan. 12	1						
Jan. 15							
Jan. 16	1						
Jan. 18	2						
Jan. 22							
Jan. 25	2						
Feb. 2	2						
Feb. 14	2						
Feb. 16	1						
Feb. 21	1						
Feb. 26							
Feb. 27							
March 5	1						
March 7	2						
March 12	2						
March 20	4	1					
March 23	1						
March 26	2						
April 12							
April 17	2						
May 2	1						
May 10	2						
May 14	2						
May 15	7	1		1			
May 16	5	4		1	1		
May 22	5	2		1			

APPENDIX II. cont.

Date	Shorthorn	Longhorn	Untagged Sculpin	Winter Flounder	Yellowtail	Sea Raven	Ocean Pout
May 24		1					
May 29	2	1					
May 30	1						
May 31	8	5		1			
June 1	4	12		1			
June 6	1	5					
June 7	6	5		2			
June 8		6				1	
June 11	8	6		1		3	1
June 12	6	7	20			1	1
June 13	7	10		2		1	
June 20	1	6		3			
June 22	8	11					
June 26	14	45	43	4			
June 28	6	18					
June 29	10	6					
July 3	8	26					
July 4	4						
July 5	5	8	17				
July 6	2	19	19	2	1	8	2
July 10		2					
July 11	1	18	13	1			
July 13	2	11					
July 16	6	20					
July 17	3	16	30		1		
July 18	2	16	20				
July 19	1	33					
July 20	5	38			1	1	
July 23	7	28	6	1			
July 25	3	25	7				
July 26	2	19			1		
July 27	2	28	13		1		
July 30		30					
July 31	3	17	3				
Aug. 7	2	10	3				
Aug. 8	1	16	8				
Aug. 9	1	12	3				
Aug. 10	1	17					
Aug. 13		2					
Aug. 20		17					
Aug. 24	2	7					
Aug. 27		8	6				
Aug. 28		6	4				1
Aug. 29		2	3				
Sept. 4		9		1			
Sept. 11		5	3				
Sept. 13		3	5				
Sept. 19		5		4			
Sept. 21		4				1	
Sept. 24		7		1			
Sept. 25	2	1					
Sept. 28		3					
Oct. 3		2	1				
Oct. 4		1					
Oct. 14							
Oct. 17	2						
Oct. 18	1	1					
Oct. 22	7	1					
Oct. 24	2						
Oct. 26	8						
Oct. 31	13						
Nov. 1	2						
Nov. 5	2						
Nov. 7	2						
Nov. 9	7						
Nov. 16	1						
Nov. 19	6						
Nov. 29							
Dec. 7							
Dec. 12	3						
Dec. 17	2						
Dec. 19	1						
Dec. 20	2						

† Where several dives were made during one 24 hour interval (ie. June 26, 1973), total numbers of fish recorded are biased upwards due to repition of counts.

APPENDIX III

Correlation Matrix for Site a

	Number of "smaller species" per square metre											
	Longhorn	Shorthorn	Arctic Shanny	Sea Snail	Ocean Pout	Radiated Shanny	Juvenile Sculpin	Water Movement	Temperature	Radiant Energy	Photoperiod	Precipitation
Longhorn	1.00000											
Shorthorn	0.30775	1.00000										
Arctic Shanny	0.04860	-0.12002	1.00000									
Sea Snail	-0.11770	-0.07256	-0.05406	1.00000								
Ocean Pout	0.12775	0.12408	-0.10335	-0.04831	1.00000							
Radiated Shanny	-0.05081	-0.06984	-0.01772	0.05996	-0.07668	1.00000						
Juvenile Sculpin	-0.02958	-0.07538	-0.00361	-0.07395	-0.11366	-0.01430	1.00000					
Water Movement	-0.20686	0.02288	0.04510	-0.06998	0.15514	0.05515	0.03373	1.00000				
Temperature	0.29503	0.10240	0.36231	-0.27305	0.07670	0.14366	0.11329	0.28514	1.00000			
Radiant Energy	0.32554	0.27803	-0.09963	0.00776	0.15506	0.07153	-0.04399	-0.21002	-0.06472	1.00000		
Photoperiod	0.38385	0.27703	0.02604	-0.01250	0.24951	0.13223	-0.09943	-0.22645	0.13620	0.71268	1.00000	
Precipitation	-0.02569	0.00842	0.05925	-0.07806	0.15189	-0.03686	0.14158	0.21863	0.13703	0.02746	0.09445	1.00000

APPENDIX IV

Correlation Matrix for Site C

	Number of "smaller species" per square metre											
	Longhorn	Shorthorn	Arctic Shanny	Sea Snail	Ocean Pout	Radiated Shanny	Juvenile Sculpin	Water Movement	Temperature	Radiant Energy	Photoperiod	Precipitation
Longhorn	1.00000											
Shorthorn	-0.11323	1.00000										
Arctic Shanny	0.20986	-0.13124	1.00000									
Sea Snail	-0.16177	0.08475	-0.25800	1.00000								
Ocean Pout	0.08194	0.05779	-0.14267	0.13193	1.00000							
Radiated Shanny	-0.13071	-0.10246	-0.07168	-0.04784	-0.04634	1.00000						
Juvenile Sculpin	0.03846	-0.12218	-0.01118	-0.23192	-0.03572	0.04260	1.00000					
Water Movement	0.07220	0.14303	0.12900	-0.18074	-0.05121	-0.06561	0.15161	1.00000				
Temperature	0.51075	-0.19829	0.38290	-0.40782	0.02099	-0.06399	0.29840	0.28123	1.00000			
Radiant Energy	0.26003	-0.11258	-0.18249	0.04449	0.32899	-0.22029	-0.07654	-0.20335	-0.06394	1.00000		
Photoperiod	0.51674	-0.20864	-0.07937	-0.00945	0.37439	-0.13305	-0.08915	-0.23451	0.13718	0.71244	1.00000	
Precipitation	0.19376	-0.02652	0.13801	-0.10993	-0.05603	-0.09286	0.02297	0.22056	0.13428	0.01796	0.09200	1.00000

APPENDIX V

Fluctuations in Concentrations of Metals (mg./litre)

		Site a						Site c					
		Magnesium	Manganese	Iron	Copper	Zinc	Lead	Magnesium	Manganese	Iron	Copper	Zinc	Lead
1973													
Aug.	30	1072.8	0.05	0.27	0.06		0.44	1072.8	0.05	0.28	0.05		0.47
Sept.	12	860.0	0.06	0.33	0.06	0.09	0.53	926.0	0.05	0.25	0.05	0.08	0.53
Sept.	17	842.5	0.05	0.30	0.05	0.07	0.49						
Sept.	25	1009.6	0.06	0.16	0.03	nd	0.54	1038.5	0.06	0.16	0.03	nd	0.52
Oct.	2	1048.1	0.07	0.19	0.03	nd	0.57	1019.2	0.06	0.20	0.03	nd	0.55
Oct.	24	1009.6	0.02		0.02	nd		1064.1	0.01		0.03	0.01	
Oct.	31	1049.1	nd	0.16	0.03	nd		1009.6	nd	0.14	0.03	nd	
Nov.	7	1009.6	0.01	0.14	0.05	nd		1019.2	nd	0.12	0.03	nd	
Nov.	16	1086.6	0.01	0.13	0.05	nd		1048.1	0.02	0.13	0.05	nd	
Nov.	29	1105.8	nd	0.15	0.04	nd		1105.8	nd	0.15	0.04	nd	
Dec.	7	1086.6	0.03	0.20	0.06	nd		1096.2	0.04	0.18	0.05	nd	
Dec.	12	1067.3	0.04	0.23	0.04	nd							

nd=not detectable